Hurdle technology: An overview of the potential food applications for creating shelf stable food products

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Abstract

In the present context there are so many innovations and developments are going on in the field of food processing and preservation, to reduce the load of chemical preservative in the processed food items and Hurdle technology is one of them. It is developed few years back with a novel concept for the development or production of stable, nutritious, tasty, safe as well as economical foods. This leads to much impressive applicability in the field of food. The hurdle technology has the usability in both developing and industrialized country for produce effective preserved food. As stated, hurdle technology is the combination of more than one technique at the same time with motive to enhance the shelf life of food product. In earlier times, hurdles were used without background knowledge for their operational principles. From past twenty years, the smart application hurdles come in to the picture prevalent because the principle behind preservation like pH, competitive flora, temperature, Eh, $a_{w,}$ etc and their relations were better understood. Recently, behavior of microbes like metabolic exhaustion, homeostasis and stress reactions along with their physiology were taken into consideration as a factor which influences method of preservation techniques with multi-target concept as emerging preservation techniques in food. In short it aims to preserve the food during the extended period of storage. Due to the different advantages, hurdle technology is just like a boon to the arising food industry especially in the developing countries.

Key words: Hurdle, preservation, homeostasis, stress reaction.

Introduction

More than 50% of food harvested been lost just because of the inadequate technologies used in developing countries. A recent report by FAO of United Nations shows, one third part of total harvested food has been lost before consumption. The surety for the destruction or removal of pathogenic microbes from food is achieved by applying hurdle technology. This shows that the shelf life of food can be improved and will be harmless for the consumption. In general, this technology works when more than one technology is combined. According to Leistner, 2000, hurdle technology is defined as combination of intelligent hurdles which ensures the stability and microbiological safety as well as preserve nutritional and organoleptic characteristic. Organoleptic characteristics

include properties such as texture, taste, smell and look. Thermal processing (both low and high temperature), reducing redox potential or water activity, increased acidity or by the addition of preservatives are the some examples of hurdles used in food processing system. Based on risk and pathogen type, hurdle intensity can be manipulated to attain based on consumer's economical way without harming the product safety. It was developed several years back. Hurdle technology involve the application of various methods (called hurdles) to attain mild and multi-target preservation impact which is reliable and possess both developing and industrialized country applicability for preserving food. Therefore the need of hurdle technology is briefly focused, also concept behind the hurdle technology along with the potential hurdles in the food preservation. The concept of hurdle technology was developed to satisfy consumer demands for healthy nutritious as well as fresh foods.

Need of hurdle technology

To fulfill the day by day increasing demands of fresh, natural, safe and healthy food items with minimal processing the research personal are continuously focusing on development of newer mild processing technology. It is also required for competing with the mountaining trends of ready to eat and convenience food in this fast ongoing era. Sometimes it also helpful in the preservation of food as it can be stored and used during the crises of food due to natural calamities like flood, drought etc. this had led the scientific aura to conceptualize the hurdle technology and some most common hurdles for effective food preservation are depicted in figure 1.

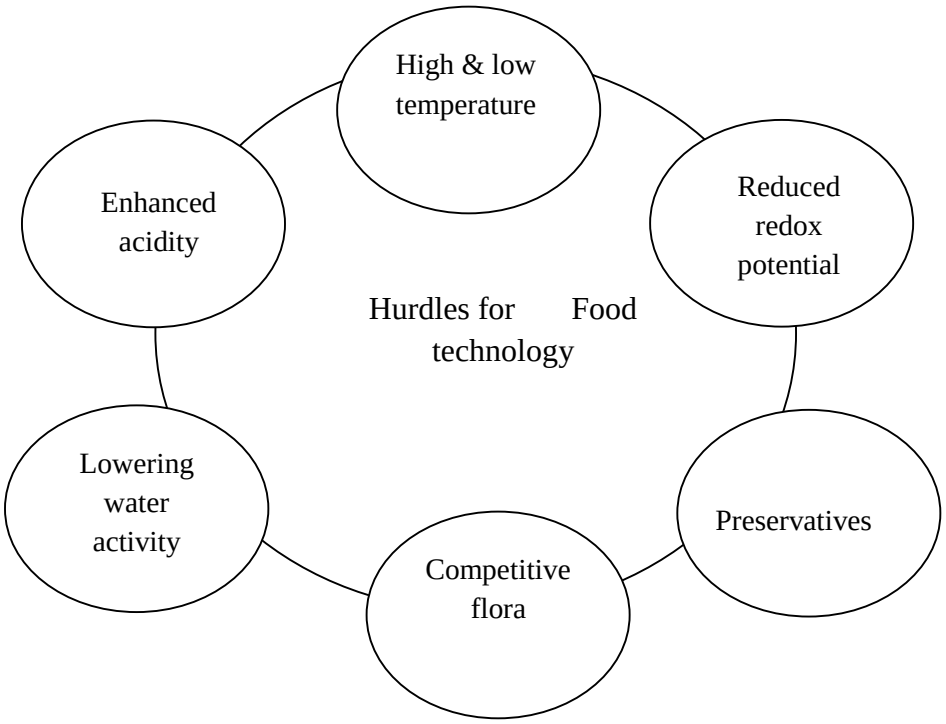

Figure 1 Some common hurdles used for preservation

Basic aspects or basic principles of hurdle technology

As mentioned previously hurdle technology involves the combination of different preservation factors as a mild but effective preservation strategy. Till date nearly more than 60 potential hurdles have been identified for potential food applications which improves the stability and quality of the food and at the same time puts in the concept of minimally processed food products with minimum damage and loss of various food bioactives which are otherwise sensitive to various harsh food processing techniques. The concept which involves multiple simultaneous preservation approaches, has been successful to various levels with different success stories in controlling pathogens and food quality during storage. Basic aspects of hurdle technology are discussed in this section.

Basic aspects of hurdle technology are as follows

Homeostasis

It is the process that maintains the stability and the internal environment of the living cells in response to the changes in external environment. Some of the examples of homeostasis in the body are regulation of temperature and balance between acidity and alkalinity (pH). These factors are prerequisite feature of living cells and this applies to the microbes as well as higher organisms (Leistner, 2000). The concept behind homeostasis is already exists in higher organisms so this knowledge should be incorporated in microbes which is important for the spoilage and poisoning of food (Leistner, 2000). Disturbing the homeostasis of the microorganisms by various hurdles eventually results in the death of the spoilage causing microbes thereby protecting the food product from microbial spoilage

Metabolic exhaustion

This aspect of hurdle technology in the food deals with auto sterilization. It was firstly investigated in the experiment carried out on liver sausages where the spores of *Clostridium* were inoculated followed by storing at 37°C (Leistner et al, 1970). Further, similar behavior of few microbial (bacteria) spores was regularly observed in meat based products which are shelf stable during storage time period (Leistner, 1994b). It has been observed that by hurdle technology, the treated food products show reduced spore count which was stored at room temperature during storage as well. The microbes in the hurdle treated stable products, if are restricted to use the metabolites of the food to fulfill their energy requirements starts to use their energy reserves for maintaining their homeostasis and thereby becoming metabolically exhausted after long times of restricted nutrient supply. This leads to auto sterilization of food products by partial inactivation of complete removal of the microbial cells associated to the food commodity. Thus, the microbiologically stable product becomes safer for storage at normal room temperatures.

Stress Reactions

Some microbes acquire resistance or under the stress condition become more virulent may conditions as they synthesize stress shock proteins when subjected to adverse growth conditions in form of various hurdles. This results in synthesis of various stress shock protiens and their nature as well as amounts is significantly affected by the type of hurdles imposed like heat, ethanol, a_w, pH, etc. The different responses of microbes under stress conditions might also hamper the method of food preservation adopted for different food products meaning that same hurdle may not be as much effective in a food as much as it was in some different. Exposure to multiple stresses simultaneously activates the energy utilizing synthesis of several stress shock proteins, in turn making the microbes metabolically weak. Hence, preservation of foods by multi-target could be an efficient approach towards reducing the stress shock proteins synthesis and in food preservation (Leistner, 2000).

Multitarget preservation

It is a very important aspect for efficient and effective preservation of targeted food material (Lesitner, 1995b). Hurdles applied in the targeted food material may not just have effects on microbial stability but they could act synergistically (Leistner, 1978). Synergistic effect could be attained in the food which is being targeted, if the hurdles affects various targets such as pH, aw, Eh, enzyme systems simultaneously in the cell of microbes which leads to disturbance in the homeostasis of the microbes rendering it difficult for the microbes to synthesise different stress shock proteins and to maintain their homeostasis (Leistner, 1995a). Therefore the application of several hurdles simultaneously would lead to an optimal microbial stability and effective food preservation (Leistner, 1994a).

Potential hurdles in food preservation

High temperature

Pasteurization:

For production of high quality food products with minimum effect on the phytonutrient, mild heat treatment like pasteurization are used to lowering the activity of microbes but not to kill them. For complete destruction or removal of harmful microorganism, this thermal inactivation method is often combined with other hurdles. Pasteurization is a method which is designed in such a manner that every single particle in the complex food matrix should receive at least definite treatment with temperature or time further cooling the products immediately which prevents any further the growth of any microorganism. This results in minimum changes in both the nutritional and organoleptic properties of the final product. Pasteurization initially was used to destroy the vegetative cells of bacteria which are mainly responsible for foodborne disease. But it also improves the shelf life of food as heating results in killing of spoilage causing microorganisms. Some most commercial time-temperature combination used for the food processing are shown in table 1. The historic background of pasteurization method named after French based the scientist Louis pasture was invented for the purpose of heating of liquid mainly beer and wine was referred as pasteurization which was further extended to

processing units of milk to destroy milk related pathogens and spoilage causing microorganisms. Traditionally, heating below 100°C referred to pasteurization (Peng et al, 2015).

Table 1 Various time-temperature combination used in pasteurization

Type of pasteurization	Time	Temperature range
HTST pasteurization	15 to 40 s	71-75°C
Batch pasteurization	30 min	62 to 65°C
High temperature operation	2-10 s	85-90°C
Beer (HTST)	2&30 s	7 I-75°C
Ice cream (HTST)	3-25 s	79-85°C

(Hasting, 1992)

Sterilization

Sterilization is defined as the heat treatment for sufficient period of time for the complete destruction of microorganism associated to a food. It is the heat treatment which results in complete destruction of microbes and their dormant spores as well. This ensures the quality retention and shelf stability of products during the storage under ambient and refrigerated storage. Sterilization does not only have the beneficial food effects however, it also results in degradation of nutrient profile of food products in terms of flavor, color and texture. The commercial sterility is commercially achieved by processing the food material at temperature more than 100°C. The steam retorts are used for sterilization which is known as autoclaving. This autoclaving method leads to complete destruction of microbes as well as spores. Sterilization involve following steps viz. heating, holding, pre-cooling and cooling.

Heating is the come-up-time required by the product to active a desirable temperature. These steps are used to estimate the energy demand required in sterilization cycle. Among all the processing steps CUT (come-up-time) was reported as the most important determinant for ther success of the sterilization process and require highest amount of energy (Peesel et al, 2016). For sterilization, full canning process is designed to attain minimum 12 log reduction of mainly spore forming microbes eg, *Clostridium botulinum* which ensure the commercial sterility. This process leads to microbial stability of food products even at room temperature for several years (Särkkä-Tirkkonen et al, 2010).

Blanching

Blanching defined as the inactivation of naturally present enzyme and their activity in food mainly, fruits and vegetables. It is commonly used practiced to destroy microorganism present in food which is to be frozen. It aids the improved shelf life of different food before their processing. Traditionally, blanching is applied for vegetables but it was also reported in the treatment for fungi, animal based foods and fruits (Reis, 2016). This method reported to possess several losses in nutritional profile of food. More than 1/3rd content of vitamin C is lost during the process of blanching. Folic acids are reported to be very sensitive towards this pretreatment

(blanching). But sterols and carotenoids were reported to be unaffected by blanching method (Puupponen-Pimia et al, 2003).

Low temperature

Refrigeration:

Refrigeration is the method which uses low temperature with the range from zero to 4℃ for the safe storage of the fresh foods as at such lower temperature ranges the microbes does not grow conveniently. This preservation method is short as the preservation effect lasts only for the time frame as long as the food sample remains under same storage atmosphere and gives the high quality of products. Refrigeration results in the changes like lowering of enzymatic reaction, reduces the microbial growth and decreased respiration rate. Refrigeration sets in the probability for the growth of pathogenic microbes like type E *botulinum.* Transportation of food through refrigeration acts as an important connective link in food chain with the purpose of maintain low temperature but also consume energy and carbon dioxide emissions (Tassou et al, 2009). Storage of food without refrigeration is in demand in the under developed countries as energy is costly and someplace is not available continuously (Leistner, 1994). Application of hurdle techniques in developing areas is important for the safe, tasty and importantly stable food without application of refrigeration. This further led the progression in the development of minimal processed foods in Latin America (Leistner, 2000).

Freezing

Freezing is done in the temperature range from -18 to -30℃. Temperature, time and product are the major factors which influence the quality. This technique practiced for preserving food products for long period. Freezing doesn't restrict the biochemical and physical reaction but slow down their reaction which is responsible for the spoilage of food. Nutritional and sensory characteristics of frozen foods can be maintained when properly processing and handling. These parameters greatly depend on the preparation of pre-freezing, freezing process and post freezing storage of the food product (George, 1993).

Reduced Water Activity (a_w)

Reduced water activity presents the availability of free water which is required for microbial growth which ultimately leads to spoilage. As a general principle lower the water activity longer the storage life of the product. Pathogenic microbes usually cannot grow at water activity below 0.60. The available free water can remove byprocesses like drying, dehydration, freezing and freeze drying. Fructose, glucose, KCl and sucrose are some food components which are responsible for reduced water activity in food material. The estimation or measurement of water activity of food can be done using various processes like Measurement of Vapor pressure, rate of sorption equilibrium (isopiestic method) and hygrometric instrument method. There are certain factors which affect the water activity of the food material including physicochemical state of food component, pressure, porous structure of food, surface tension, food components and temperature (Rehman and Labuza, 2007).

Increased Acidity or Lowered pH

Acidity and pH are helpful in restricting the growth of microorganism and other harmful pathogens and further germination of spores generally below 4.5 pH. Organic acids like lactic acids, malic acids, benzoic acid, citric acid and tartaric acid present on food which lowers the pH. pH and acidity are two interconnected concepts in analysis of food. They both are estimated separately and each of them has their own effect on quality of food. Acidity mainly deals with the concentration of total acids present in food which is generally measured by titratable acidity. Whereas, pH only estimate the concentration of H_3O^+ which is called as active acidity. Mostly, food is complex in nature. They possess many acidic compounds in their kreb's cycle such as amino acids and fatty acids. On the theoretical basis, such compounds also contribute to the overall titratable acidity i.e, total acidity (Sadler and Murphy, 2010).

Redox potential

Hurdle technology is an integrated approach by the means of which preservation parameters can be enhanced up to a certain level in order to achieve a maximal lethality against microbes by employing two or more techniques in combination so as to keep degradation of sensory aspects to minimal level. All the while redox potential is acknowledged as an important hurdle approach to expand shelf life of various food products. In food industry, as example to detect the fermentation activity or to inspect aerobic & anaerobic growth microbial growth in food samples. Redox potential being one of the potential hurdles for food analysis which is used to enhance stability and quality of foods works on estimating the potential difference in a particular food or system. It is mainly affected by chemical compositional structure, processing and storage conditions of the food.

Preservatives role in hurdle technology

Consumer demands for natural foods demands from food manufactures to go for mild preservation techniques such as refrigeration, modified atmosphere packaging, but this does not provide much freshness to products. The concept of hurdle technology is a combined effect that prevent food products from different microbial spoilage. These hurdles are temperature, pH, redox potential.

The hurdle technology helps to avoid pathogen attack. Food preservatives helped by disturbing the homeo-statis of microorganisms microorganisms. Hurdles effect the cell memebrane, enzymes, pH & help to avoid microbial attack. The most common preservatives used for food preservation include salts of Potassium Metabisulphite, benzoates Apart from the preservatives action they have also been reported to cause some toxicity beyond uses against recommended doses. Hurdle technology quant the processors with options to use the preservatives below far lower level than recommended doses which eliminates the possibility of toxicity.

Table 1 Effect on shelf life of food product with type of hurdles

Food	Shelf life	Hurdle	Reference
La Chang (meat) China	2–3 months	Sugar: 4–20 % pH: 5.9–5.7 Total count < 10^6/g NaCl: 3–5 % aw: 0.85–0.70 Refrigeration: No	Rehman, 2015
Paneer in gravy (India)	2 weeks (Storage: 45 °C) 1 month (Storage: 30 °C) 3 months (Storage: 15 °C)	Potassium sorbate: 0.1 pH: 5.0 aw: 0.95	Rehman, 2015
La Chang (meat) China	4–5 months	pH: 5.9–5.7 Refrigeration: No aw: 0.85–0.70 Packaged: vacuum Sugar: 4–20 % Total count < 10^6/g NaCl: 3–5 %	Rehman, 2015

Hurdles in foods

The following types of techniques are used as a hurdles for the preservation of food are acidity (pH), a_w, high temperature, low temperature, preservatives (e.g., nitrite, sorbate, sulfite), redox potential (Eh), and competitive microbes (e.g., LAB). Other hurdles like products from millard reactions affects the quality and safety of food as they possess antimicrobial characteristics as well as enhance the flavor at same time. This hurdle can have both negative and positive influence on food products according to their intensity. Hurdle Technology as novel concept recently has been applied for the preservation of different type of food products like:

Dairy based products

Hurdle technology has its influence in dairy as it has been useful to enhance the shelf life of various products processed in an industry. Use of hurdles such pH, aw, Modified Atmospheric Packaging for the preparation of shelf stable paneer is in practice till date. This technique provides paneer a shelf life of one to twelve days when stored at normal conditions or ambient conditions, or if stored in refrigerator it can be consumed between six to twenty days with optimum sensory and physiochemical properties. (Thippeswamy et al, 2011) Further extension of shelf life and improvisation in nutritional aspects of dairy products carried out in different researches so far. (Panjagari et al, 2007)

Fruits & Vegetables

Number of hurdle has been used in the preservation of various fruits and vegetables like pineapple, carrot, coconut and papaya to increase stability and shelf life of fruits and vegetables. Shelf stable grated carrot products is developed by applying hurdle technology with the help of several hurdles such as antimicrobials, partial dehydration and packaging in polymeric bags.(Vibhakara et al, 2006) develop grated carrots that can remain fresh and microbiologically safe for more than six months at ambient temperature. Several other technologies are

still under way for the development of shelf stable fruits and vegetables as the presence of high amount of water hinders their storing practices, several researches has developed these practices considering the requirements and needs of the consumer (Alzamora et al, 1993; López- Malo et al, 1994; Gunathilake, 2005; Saxena et al, 2009; Gomez et al, 2011; Sankhla et al, 2012)

Meat and meat products

Use of Hurdle technology for number of meat products is in practice due to the perishability of meat products. Thomas et al., 2010 investigated the effect of different hurdles (pH, vacuum packaging, aw and post package treatment) in pork sausages at refrigerated temperature (Thomas et al, 2010; Malik and Sharma, 2014). Food for space scientist and mountaineer was difficult to sustain before the outbreak of Hurdle Technology, which has turn now a days to an easier task as ever before, for the development of meat product and shelf stable ready to eat foods. Karthikeyan et al., (2000) gives their contribution in the production of caprine keema which is shelf stable at ambient temperatures by the application of hurdle technology in which the hurdles like aw, pH vacuum packaging, heat treatment and preservatives has been used. The shelf life of keema developed by the use of hurdle technology was found to be stable until fifth day of storage unlike the normal keema because of its high perishability, have to be consumed on the same day it is prepared. Other products such as chicken lollipop by the use of different hurdles have developed by Singh et al, 2014. Growth of economy leads to an increase in demand in minimal processed food and food products. Conventionally the food was preserve by the use of single parameter that leads to the destruction of both sensory as well as nutritional qualities. On the other hand use of hurdle technologies undoubtedly reduces these losses and produce product more valuable and fit according to the consumer demands.

Conclusion

The physiological responses of microorganisms during food preservation (i.e., their homeostasis, metabolic exhaustion, and stress reactions) are the basis for the application of advanced hurdle technology. Use of hurdle technology improves the product quality along with shelf life and microbial safety of the food products. It also one of the newer methods of food preservation which is well established to improve economy, time, energy and several other resources. The multiple food preservation techniques applied synergistically to the food renders it stable, safe and high in nutritive due to gentle process applied. It is a method which is applicable to small as well as at large industries. Due to these reasons hurdle technology seems to be a boon for food industry and this should become definitely a major research topic in the years to come to explore the particular mode of action of different factors and their interaction with the microorganisms.

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